Porous Material for Protection from Electromagnetic Radiation

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Abstract. It is shown that the porous glass crystalline material obtained by a low temperature technology can be used not only for thermal insulation, but also for lining of rooms as protective screens decreasing harmful effect of electromagnetic radiation as well as to establish acoustic chambers and rooms with a low level of electromagnetic background. The material interacts with electromagnetic radiation by the most effective way in a high frequency field (above 100 GHz). At the frequency of 260 GHz the value of the transmission coefficient decreases approximately in a factor times in comparison with foam glass.

Keywords: foamglass crystal material, absorption of electromagnetic energy, ecology, dielectric permittivity spectra, electromagnetic response

INTRODUCTION

Electromagnetic radiation of all frequencies is one of the most widespread and rapidly growing influences on the biological and physical objects. The emission in a radiofrequency and microwave range influences both human health and the work of different devices including computers, transformers, medical equipment [1, 2]. In connection with the increasing background of electromagnetic radiation questions of the radioprotective materials development of different purpose become especially urgent [3, 4].

From an ecological point of view, electromagnetic radiation is one of the forms of energy pollution of environment. Super high frequency-furnace, cell phones, personal computers, radio communications, radio navigation and radar devices are the main sources of background noise [5]. At present the materials, which possess the properties of protection from the electromagnetic interferences, have large prospects and practical value for civil sphere, electronic and biomedical engineering. There is a wide variety of radioprotective materials, which differ in composition, structure and form. One of the promising groups is the porous materials of inorganic nature, such as foam glass, cellular concrete, foam gypsum. According to work [6] protective efficiency of foam materials is more than 15 dB and at 4 GHz specific adsorption is more than 4 dB/cm. For example, at 1 GHz the protective efficiency of flexible graphite reaches 130 dB.

In addition to radioprotective properties low thermal conductivity, density and fire safety are important properties too. Among these materials foam glass possesses additionally high technological effectiveness and possibility to obtain material with developed surface in the form of pyramids. Application of additional layer of foam glass with pyramidal topography ensures multiple reflections of emission on the pyramids and decreases reflectivity. The closed cellular structure of foam glass, atmosphere and frost resistance, stability of physical

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properties and longevity allow speaking about the highly effective building material. If absorptive ability of foam glass increases, it can be used in the wide range of temperatures and humidity as the effective absorber of electromagnetic waves.

Purpose of the work is to compare the parameters of electromagnetic response (transmission and the reflection coefficients) of foam glass materials obtained by traditional powder technology from broken glass and synthesized ones by the low temperature technology of glass crystalline product (further foam glass the crystalline material) in the range of 26–260 GHz.

OBJECTS AND METHODS OF RESEARCH

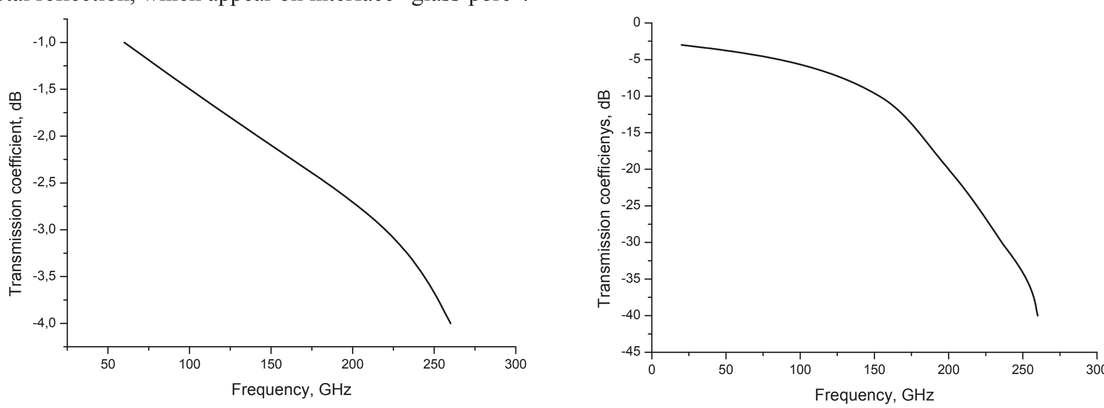
Various forms of accessible and extended natural raw materials as well as industrial wastes have been tested as initial raw material to obtain foam glass crystalline materials. Using different raw material and selecting the optimum temperature conditions of synthesis in each specific case it is possible to control macro- and microstructure of material, changing its properties in wide range [7, 8]. In this work material, obtained on the basis of siliceous raw material, has been selected for study. The reflection and transmission coefficients were measured by the method of free space using a radio spectroscope built around an E8363B Vector Network Analyzer (Agilent Technologies) in the range 26–36 GHz and an STD-21 teraherz spectrometer in the range 60–260 GHz [9].

RESULTS AND DISCUSSIONS

Study of electromagnetic characteristics of the samples showed that both materials effectively interact with electromagnetic radiation. In this case the reflection coefficients of the samples are approximately identical and practically equal to zero, which is determined by the absorbing properties of material. In both cases one form of gas developing agent (carbon black), which responds for three-dimensional organization of charge carriers, is used. Passing of radiation through the sample is reduced to a larger degree in the field of high frequency range for foam glass crystalline material (Fig. 1), that is explained by presence of dipoles in the material and values of dielectric permeability differing from foam glass.

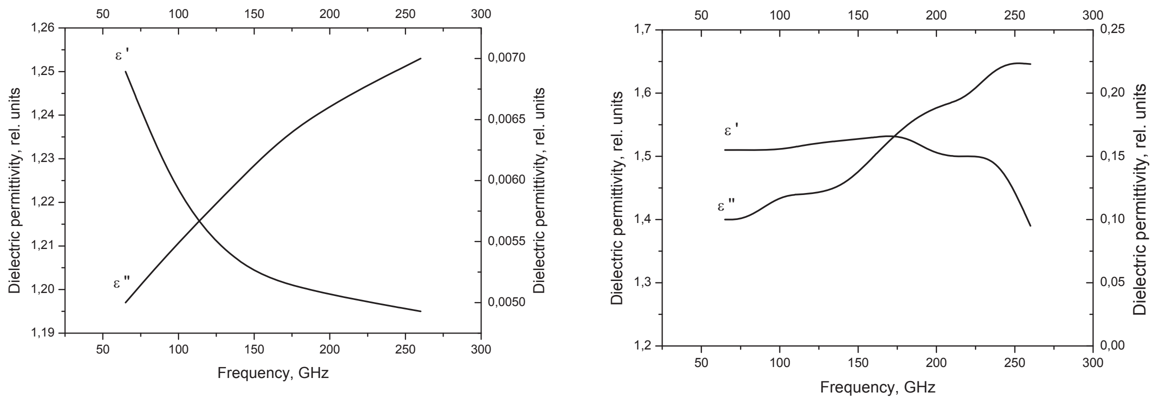
The samples of foam glass crystalline material have large values of dielectric permeability, that characterizes it as material with higher degree of polarization (Fig. 2). These data confirm results of IR-spectroscopy. It is stated that the band of 1088 cm^{-1} is absent in foam glass obtained from the broken glass. It corresponds to the fluctuations of non-bridge links Si–O–Si, as well as absorption band, which relates to valence vibrations of OH-groups, appear in the samples of foam glass crystalline material.

Physical mechanism, which explains absorption of electromagnetic radiation in material, induces from one side the presence of ultra-dispersed particles of carbon. The particles interact with the field and form electrically conducting carcass, and from other side diffusing power of porous system due to existence of fields of partial and total reflection, which appear on interface "glass-pore".



(a) (b)

FIGURE 1. Parameters of the electromagnetic response of the sample synthesized from commercially available glass cullet (a) and foam glass crystalline material (b)

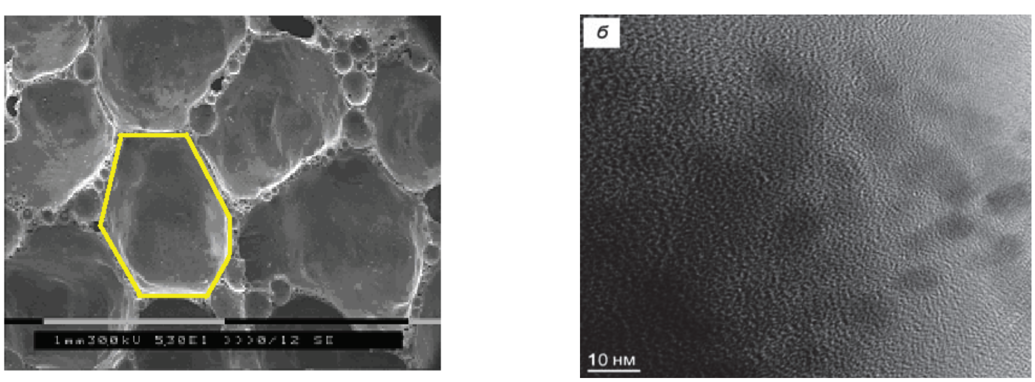


(a) (b)

FIGURE 2. Spectra of the complex dielectric permittivity of the sample synthesized from the commercially available glass cullet (a) and foam glass crystalline material (b)

Studies showed that differences of electrophysical indices of the sample are caused by differences of their micro- and macrostructure. Average sizes of pores of foam glass crystalline material and foam glass are 0.8 and 1.2 mm respectively, form of pores is hexagonal in the first case and spherical in the second one (Fig. 3). These differences are caused by presence of residual crystalline phase in interpore partition. Electronic micrographs of high resolution show nanosized structural elements in the amorphous matrix of obtained foam glass crystalline material, which can be represented as particles with quartz or cristobalite structure with one-dimensional SiO-chain on their surface. There is formation of the micro-globules, which is absent in foam glass obtained from broken glass in this glass phase.

Undertaken study showed that the researched materials have practically zero reflection coefficient, that is defined by both their absorbing properties and by diffusion power of diffuse surface of porous material. Foam glass crystalline material obtained by low temperature technology possesses not only higher strength in comparison with foam glass obtained from broken glass but also the improved radio absorption properties. Material interacts with electromagnetic radiation by most efficient way in high frequency field (above 100 GHz). At frequency of 260 GHz value of transmission coefficient decreases approximately in a factor times in comparison with foam glass.



(a) (b)

FIGURE 3. Structure of the interpore partition of foam glass crystalline material: (a) hexagonal form of pore, (b) nanoglobular structure of interpore partition

CONCLUSION

It is possible to control electromagnetic characteristics changing the structure of foam glass crystalline material, form and sizes of micropores, structure of interpore partitions, value of the dielectric permeability of carcass. Foam glass crystalline material may be recommended to use not only as thermal insulation, but also as lining of rooms (in the form of protective screens) decreasing harmful effect of electromagnetic radiation, as well as to establish acoustic chambers and rooms with low level of electromagnetic background. At this case working temperature range and longevity of material are higher in comparison with other radioprotective materials.

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